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Environmental - Remediation - Engineering - Laboratories - Drilling

GEOTECHNICAL INVESTIGATION REPORT

No. 1 Fern Creek Road Warriewood, NSW 2102

Prepared for

DEP (Warriewood No. 2) Pty Ltd

Report No. GS5895/2A

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REFERENCES

1. Australian Geomechanics Society Landslide Taskforce, "Practice Note Guidelines for Landslide Risk Management – AGS 2007c", Vol. 2 No. 1 March 2007.
2. Australian Standard AS1726-1993 Geotechnical Site Investigation.
3. Australian Standard – AS 2159-2009 Piling design and installation.
4. Australian Standard – AS 2870-2011 Residential Slabs and Footings.
5. Australian Standard – AS1170.4-2007 Structural design actions - Earthquake Actions in Australia.
6. Australian Standard – AS3798-2007 Guidelines on earthworks for commercial and residential developments.
7. Pells, P.J.N, Mostyn, G. & Walker B.F., "Foundations on Sandstone and Shale in the Sydney Region", Australian Geomechanics Journal, 1998.
8. Pittwater Council Local Geotechnical Risk Property Enquiry http://www.pittwater.nsw.gov.au/building__and__development/property_information/landslide_geotechnical_risk.

1. INTRODUCTION

Aargus Pty Ltd (Aargus) has been commissioned by DEP (Warriewood No. 2) Pty Ltd to carry out a geotechnical site investigation at No. 1 Fern Creek Road, Warriewood, NSW 2102. The site investigation was carried out on the 1st and 2nd of July 2014 and was followed by laboratory testing, geotechnical interpretation, assessment and preparation of a geotechnical report.

The purpose of the investigation was to assess the ground conditions and feasibility, from a geotechnical perspective, of the site for a proposed residential subdivision development. The investigation included assessment of the site existing geotechnical conditions and providing general recommendations for design and construction of the proposed subdivision development.

This report presents results of the geotechnical site investigation, laboratory testing, interpretation, and assessment of the site existing geotechnical conditions, as a basis to provide general recommendations for design and construction of ground structures and pavement for the proposed development.

To assist in reading the report, reference should be made to the "Important Information About Your Geotechnical Report" attached as Appendix A.

2. AVAILABLE INFORMATION

Prior to preparation of this report, the following information was made available to Aargus:

- Drawings of the proposed residential subdivision and development at No. 1 Fern Creek Road Warriewood, NSW prepared by Stephen Bowers Architects, consisting of drawing nos. DA-001, DA-004, DA-005 and DA-006, dated 22nd July 2014; and
- Survey plan titled "Plan Showing Contours and Detail on Lot 1 in DP736961 and Part of Lot C1 in DP376390 being No. 1 Fern Creek Road and 12 Orchard Street, Warriewood" prepared by Brunskill McClenahan & Associates Pty Ltd, reference 14042-3.DWG, Sheet 1 of 1 and dated 8th July 2014.

3. SCOPE OF WORK

In accordance with the brief, fieldwork for the geotechnical site investigation was carried out by an experienced geotechnical team from Aargus following in general the guidelines provided in Australian Standard AS1726-1993 (Reference 2) and comprised the following:

- Collection and review of Dial-Before-You-Dig (DBYD) plans;
- A site walkover inspection by a Principal Engineering Geologist in order to determine the overall surface conditions and to identify any relevant site features;
- Machine drilling of nine boreholes identified as BH1 to BH9 inclusive using a truck mounted drilling rig owned by Aargus and operated by BG Drilling Pty Ltd. Boreholes BH1 to BH4, inclusive, BH6 and BH7 were drilled to V-bit refusal thence advanced and terminated at Tungsten Carbide (TC) bit refusal, with depth of augering achieved varying from approximately 1.5m to 6.5m below ground level (bgl);
- Drilling of boreholes BH4 and BH7 continued after TC bit refusal with coring using NMLC technique to approximately 3.6m and 5.7m bgl respectively;
- Three boreholes being BH5, BH8 and BH9 were drilled using a 450mm diameter auger;
- Boreholes BH8 and BH9 were drilled to obtain samples for laboratory testing. These boreholes were drilled to V-bit refusal at approximate depths of 0.6m and 1.0m bgl, respectively;
- Standard Penetration Tests (SPT) conducted within the boreholes to assess the in-site strength of subsurface soil layers;
- Installation of standpipe piezometers in two of the boreholes, being boreholes BH6 and BH7 to approximately 3.0m bgl;
- Dynamic Cone Penetrometer (DCP) testing was conducted at six locations identified as DCP1 to DCP6 inclusive to augment the borehole data;
- Collection of soil samples during drilling; and
- Reinstatement of the boreholes with soil cuttings.

Boreholes BH1 to BH7 inclusive were positioned at locations close to the footprints of the proposed building platforms of the proposed residential lots. Boreholes BH8 and BH9

were positioned within the central portion of the site within the footprint of the proposed subdivision road.

The approximate locations of the boreholes and DCP tests are shown on Figure 1, "Site Plan" attached as Appendix B.

Following completion of the site investigation, laboratory testing was carried out on selected soil samples recovered from the site investigation boreholes, which consisted of:

- Laboratory testing on two recovered soil samples for determination of 4 days socked California Bearing Ratio (CBR).

Following completion of the site investigation and laboratory testing, Aargus carried out geotechnical interpretation of the results and assessment of the site suitability for subdivision and the proposed building development together with assessment of the site classification and the geotechnical aspects that may be associated with the proposed development. A geotechnical report was prepared to summarise the results of the geotechnical site investigation, interpretation and assessment. The information provided in this report includes:

- Method of investigation;
- Site description, including surface and subsurface conditions;
- Site plan indicating relevant locations of the proposed development, boreholes and DCP tests;
- Subsurface conditions together with material characterization;
- Borehole logs;
- Results of field and laboratory testing;
- Geotechnical profile for the site;
- Indications of groundwater levels as encountered during the investigation and recommendations for drainage measures;
- Assessment of potential geotechnical issues that may be associated with the proposed development;
- Site classification in accordance with Australian Standard AS2870-2011;
- Landslide risk assessment;
- An indication of the nature and condition of the materials to be excavated;
- Design parameters for retaining walls with comments on suitable wall types for this site;

- Recommendations on foundation types and design for shallow and deep foundations;
- Site specific "Subsoil Class" for earthquake design in accordance with AS1170.4-2007; and
- Recommendations as to excavation methods in rock and measures as may be applicable to restrict ground vibrations.

4. SITE DESCRIPTION

The site is located within the Pittwater Council area, at approximately 22 kilometres to the north of Sydney CBD and 2 kilometres to the west of Mona Vale Public Hospital in the vicinity of Mona Vale Beach. The site is bounded by the following properties and public roads:

- The property with legal description of Lot 2 of DP736961 to the north where the common boundary is 95.77m in length;
- Orchard Street carriageway and road reserve to the south, where the front boundary is 98.41m in length;
- Fern Creek Road carriageway and road reserve, to the east where the boundary is 169.88m in length; and
- The property at No 14. Orchard Street described as DP369510 Lot B1, to the west.

The site consists of amalgamation of three properties being:

- Lot 1 in DP736961, which is an irregular shaped parcel of an approximate area of 1.324 hectares and with maximum dimensions approximately 120m from east to west and 150m from south to north;
- An access driveway property with legal description of Lot C1 DP376390 within the western portion of the site, of an approximate area of 1,430m^2; and
- A strip of land to the south of the main parcel along the frontage with Orchard Street, being Lot 103 DP1033854, of an approximate area of 511m^2.

The site locality is within the eastern portion of the toe of remnants of a spur that is trending in a North West to South East direction. The spur head is inferred to be located at approximately 1.25 kilometres to the north-west of the site, in the vicinity of Mona Vale Road. The site is located to centrally across an elongated knoll trending in west to east

direction. The knoll has a broad gently sloping crest with moderately steep flanks. The morphology of the landscape appears to have resulted from resistant sandstone bed/s, which caps the hillside overlying less resistant sandstone beds including some shale beds.

The majority of the site is currently vacant apart from a two story residential dwelling (house) and a garage located within the central area, at the top of the knoll (hilltop). Access to the house is from Orchard Street though a concrete driveway.

The survey plan referenced in Section 2 above, indicates two easement strips for electrical transmission lines are present across the middle of the site from the south to the north. The easements are 4.57m wide each and located to the west of the existing house and garage.

The majority of the area surrounding the existing buildings, driveway and the easements are currently occupied by mature trees and scrub.

It is understood that limited earthworks were undertaken during construction of the existing house where some levelling was undertaken on the hilltop area and minor terracing was undertaken on the slopes below. It also inferred that some earthworks, mainly cutting, were carried out outside the site eastern boundary, alongside the Fern Creek Road to create the road carriageway and shoulders.

Based on the existing topography and the underlying soils encountered during the site investigation, the site can be divided into three geomorphic zones being Zone A , Zone B and Zone C. Zone A is the reasonably flat and gently sloping area within the elevated hilltop area and Zone B is the moderately to steeply sloping ground below and surrounding Zone A. Zone C is relatively very narrow and short strip of gently sloping ground at the toe of Zone B, within the site northern corner, which is underlain by shallow alluvial deposits.

The approximate boundaries of the three geomorphic zones designated by Aargus are depicted on the site plan, Figure 1 in Appendix B. Brief description of the three geomorphic zones is presented below:

- Zone A: Is the central area of the site, including the existing house and outdoor structures area and the surrounding gently to moderately convex sloping areas

typically ranging between less than 5º steeping to about 9º away from the hilltop towards generally all directions. The ground surface varies in elevation from approximate elevation of RL34.0m Australian Height Datum (AHD) within the outer boundaries to approximately RL39.0m within middle portion of Zone A.

- Zone B: Is the moderately steep to steep concave slopes around the perimeter of the hilltop with slopes typically ranging between 11° and 22° and locally steeper areas of about 26°. In places these slopes are terraced with man made and natural soils and rock outcrops. Areas of sandstone outcrop and scree are common on some of the steeper portions of this zone particularly along the north west facing slopes. Minor steep road cuts occur in places along the access driveway as well as along the boundary with Fern Creek road reserve, which have exposed the weathered sandstone. There is a heavily vegetated cover and numerous mature trees scattered within this zone.

- Zone C: This zone consists of a relatively small area located within the northern corner of the site at the toe of the lower northern slopes of Zone B, where the ground surface slopes towards the north. The ground surface slopes range between 2° to 7° towards northern corner of the site. This area is currently used as part of horse paddock with a stable and sheds are located. During the site investigation the paddock was covered with grass with some areas of bare soil and areas of sandstone boulders.

Selected photographs of the site are attached as Appendix C.

5. PROPOSED DEVELOPMENT

The provided drawings and information provided through email correspondence with the project manager indicate the proposed development consists of the following:

- Subdividing the site into 17 lots being Lot 1 to Lot 17 inclusive, which are shown on Figure 1 in Appendix B;
- Lots 2 to 17 will be developed for individual residential dwellings with the existing dwelling located on Lot 16;

- No building footprint was shown within Lot 1, which is located at the south eastern corner of the site, at the north western corner of the Orchard Street and Fern Creek Road intersection. This lot will be used as a public park;
- A new a cul-de-sac rising up onto the hilltop area from the existing access driveway, Lot C1 DP376390 within the western portion of the site, off Orchard Street from a point approximately midway along the western boundary;
- An access driveway is proposed alongside the north western boundary;
- No building platforms will be located within the transmission easements;
- The approximate land areas for the proposed lots range between 544m^2 and 1000m^2; and
- The residential buildings will likely consist of two storey dwellings with a semi basement cut into the hill side for the lots located within sloping areas.

Further details are shown on the drawings of the subdivision plan referenced in Section 2.

6. LOCAL GEOLOGY

Reference to the Sydney 1:100,000 Geological Series Sheet 9130 Edition 1, dated 1983, by the Geological Survey of New South Wales, Department of Mineral Resources – Sydney, indicates the site is located within an area underlain by Hawkesbury Sandstone of the Wianamatta Group, underlain by the Newport Formation of the Narrabeen Group.

The Hawkesbury Sandstone, which is denoted as Rh generally consists of medium to coarse-grained quartz sandstone, with very minor shale and laminate lenses. The knoll capping is inferred to be an outlier of the Hawkesbury Sandstone Formation.

The Newport Formation, which is denoted as Rnn, is inferred to underlie the hilltop at depth beneath the Hawkesbury Sandstone Formation. The formation is described as "Interbedded laminate, siltstone, shale and quartz to lithic-quartz sandstone with clay pellet sandstone, which exhibits strongly developed bedding and jointing".

7. INVESTIGATION RESULTS

7.1 Surface Conditions

During the site investigation, the majority of the site surface was generally covered with grass and topsoil. The existing access driveways were covered with either concrete or road-base gravel, and the footprints of the existing structures typically are covered with foundations and floor slabs.

The topsoil underlying the majority of the site varied in thickness from 100mm to 200mm and consisted of grey brown, loose to medium dense, dry to moist silty sand.

7.2 Subsurface Conditions

The subsurface conditions encountered within the boreholes BH1 to BH7 inclusive, are detailed on the attached Engineering Borehole Logs presented in Appendix D. As boreholes BH8 and BH9 were drilled for sampling only, no logs have been prepared for these boreholes. The results of DCP testing are presented in Appendix E.

A Generalised Geotechnical Cross Section A-A' attached as Figure 3 in Appendix G, was prepared to provide an indicative subsurface profile across the three geomorphic zones designed by Aargus described above. The cross section was prepared based on the boreholes positioned at those locations, which are depicted on the cross section.

The results of the geotechnical site investigation indicated the site is underlain by relatively complex geology but in general, relatively consistent with the published geology.

Summary of the subsurface conditions encountered during borehole drilling and DCP testing at this site is presented below for each of the three zones designated by Aargus.

Zones A and B

- Insitu silty Sand generally less than 1.0m in thickness, consisting of grey brown and dark grey brown, loose to medium dense, dry to moist, fine to medium grained with gravels.
- Scattered high strength sandstone outcrops and boulders occur in places across and around the perimeter of the hilltop within Zone A as well as at scattered locations

within the slopes of Zone B. Some of the large boulders appeared to have been moved during landscaping.

- In places the insitu silty Sand is capped with minor layers of fill which appeared to comprise reworked insitu soils, of up to approximately 1.0m in thickness as encountered in borehole BH3; overlying
- Relatively thin orange residual medium dense to dense Sand with some gravel grading to very low to medium strength completely weathered sandstone, underlying the upper insitu silty sand and possible sandstone boulders at some locations, extending to depths varying from approximately 1.0m to 1.8m bgl.
- High to very high strength sandstone boulders and surface outcrops, inferred to be overlying weathered lower strength Class V Sandstone as observed in a number of surface exposures across the site and encountered during augering using V-bit and TC-bit.
- At some locations, the sandstone boulders are underlain by colluvial soils and crushed sandstone cobbles and boulders.
- Highly to moderately weathered sandstone, consisting of orange, very low to low strength sandstone, extending to approximately 3.0m below natural ground. TC bit refusal was reached at a depth of 2.7m in borehole BH7.
- Interbedded residual soils, completely weathered siltstone and thin sandstone bands overlying extremely weathered shale, were encountered during coring in borehole BH7, which confirmed the presence of Newport Formation materials underlying the upper materials of the Hawkesbury Sandstone Formation.
- The depth and stratification of the soil and rock horizons belonging to the Hawkesbury Sandstone Formation and the Newport Formation are inferred to vary on the slopes of Zone B depending on the ground elevation.

Zone C

- A superficial layer of sandy hillwash consisting of orange brown to orange with red mottles, stiff to very stiff alluvial sandy and silty Clay, which extends to approximately 2.0m bgl. The recorded SPT 'N' value in this unit was 16blows/300mm penetration; overlying

- Residual soils, consisting of pale grey with pale red mottling, very stiff to hard, silty Clay, extending to approximately 6.5m bgl where V-bit refusal occurred; overlying
- Inferred soil and rock horizons of the Newport Formation.

Classification of the rock is based on the guidelines provided by Pells et al (Reference 7).

Results of DCP testing at scattered locations within the site indicated the surficial insitu soils have generally firm to stiff consistency.

7.3 Groundwater

No seepage was encountered during drilling of the augered boreholes. Standpipe piezometers were installed to approximately 3.0m bgl in two of the boreholes being BH6 and BH7, which were both dry when measured about two weeks after completion of the borehole drilling. No surface seepage or hydrophilic vegetation was observed on the site during the site investigation.

Based on the site topography, groundwater flow is expected to be likely towards the east and north east.

It should be noted that groundwater levels may be subject to seasonal and daily fluctuations influenced by rainfall and other factors such as flooding and future development of the surrounding lands.

7.4 Geotechnical Laboratory Testing

During the course of the investigation, samples were obtained from within the depths of the boreholes. Selected samples were tested for determination of California Bearing Ratio (CBR) for pavement design with testing being carried out by Aargus NATA accredited laboratory in accordance with the following standard:

- Australian Standard AS1289 6.1.1 - Determination of California Bearing Ratio of a Soil – Standard Laboratory Method for a Remoulded Specimen.

The results of testing for determination of CBR are summarised in Table 1. The laboratory test result sheets are attached in Appendix F.

Table 1: Results of laboratory testing for determination of CBR

Borehole	Depth Range (m)	Sample Description	CBR (%)
BH8	0.2 – 0.8	Silty SAND	70.0
BH9	0.1 – 0.35	Gravelly SAND	60.0

8. GEOTECHNICAL ASSESSMENT

8.1 General

The main geotechnical aspects associated with the proposed development are assessed to include the following:

- Site specific classification;
- Excavation conditions;
- Stability of excavation;
- Landslide risk;
- Excavation retention;
- Foundations;
- Drainage;
- Site earthquake classification; and
- Pavement design.

A summary for assessment of the geotechnical aspects above and recommendations for design and construction of the proposed development is presented in the following sections.

8.2 Preliminary Site Specific Classification

Zone A

The site investigation data obtained from boreholes BH3 and BH5 and DCP tests 4 and 5, which were positioned within Zone A, indicated the area is underlain by a generalised profile consisting of a relatively thin layer of low plasticity silty sand extending to approximately 1.0m bgl, overly weathered sandstone. Existing man made fill may be

present at isolated locations. Based on our observation and the results of site investigation, it is considered that the soils underlying Zone A are generally non to slightly reactive. These soils will likely to be present within reasonably level or gently sloping ground, limited in thickness and will likely to be subject to partial or complete removal during foundation construction. Review of the investigation data with reference to Australian Standard AS2870-2011 "Residential Slabs and Footings" (Reference 4), indicated that the site can be classified as Class "S" within areas of limited thickness of insitu soils, with areas underlain by fill to be classified as Class "P".

Zone B

Data of boreholes BH1, BH2, BH4 and BH7 and results of DCP tests 1 to 3 inclusive and 6, indicated Zone B is underlain by a generalised profile consisting of shallow sandy topsoil and residual silty sand extending to depths varying from approximately 1.0m to 1.8m bgl overlying competent weathered sandstone. In some areas localised fill and hillwash of up to approximately 1.0m in thickness are present. Review of the investigation data with reference to Australian Standard AS2870-2011, indicated that the site can be classified as Class "M" within areas of limited thickness of residual soils, with areas underlain by fill and hillwash to be classified as Class "P". Review of the currently proposed dwelling locations on the drawings of the proposed development referenced in Section 2 indicate the dwellings in Zone B will likely extend over sloping ground and will likely have variable foundation conditions ranging from deep clays to weathered sandstone. Based on conventional foundation design, building platforms within sloping grounds may be subject to downslope movement (i.e. creep). Therefore Zone B should entirely be considered as Class "P".

Zone C

The investigation data, of borehole BH6, indicated Zone C is underlain by alluvial clay extending to approximately 2.0m bgl, which is underlain by residual clay derived from weathering of the Newport Formation shale, siltstone and sandstone horizons. Based on our experience with the local soils, it is considered that the clayey soils underlying Zone C are highly reactive. Review of the borehole data with reference to Australian Standard AS2870-2011, indicated that Zone C should be classified as Class "H1", i.e. highly

reactive clay site, which may experience high ground movement resulting from moisture changes. In some areas localised fill and hillwash of up to approximately 1.0m in thickness are present. Areas underlain by fill and hillwash should be classified as Class "P".

Site specific geotechnical investigation will be required for each residential lot in order to confirm the site classification following completion of the subdivision earthworks. Typically, borehole drilling investigation is carried out within cut areas and borehole plus field density testing are carried out within fill areas for the purpose of site classification.

8.3 Excavation Conditions

Excavation as part of earthworks for preparation of proposed building platforms, access driveways, basements within the sloped areas (i.e. Zone B), trenching for underground service and foundations will vary from a location to another for the proposed residential lots 2 to 17.

Excavation in fill, alluvial-colluvial and residual soils as well as extremely weathered sandstone and shale horizons will be typically feasible using conventional earthmoving equipment.

The high strength sandstone outcrops and large sandstone boulders may hinder excavations in zones A and B will likely require large excavators /rock cutting and vibratory rock breaking equipment.

Provided appropriate screening and conditioning is undertaken, and that the materials are verified from environmental perspective, the excavated materials are assessed to be suitable in general for reuse in earthworks.

8.4 Vibration Control

As heavy ripping, rock breaking equipment or vibratory rock breaking equipment is expected to be required for the high strength sandstone outcrops and large sandstone boulders and due to the presence of the existing house and associated structures within the site, to ensure vibration levels remain within acceptable levels and minimise the potential

effects of vibration, excavation should be complemented with saw cutting or other appropriate methods prior to excavation.

Consideration should be given for rock saw cutting using an excavator mounted rock saw, or the like, so as to minimise transmission of vibrations to any adjoining properties that may be affected. Hammering in some areas such as in the vicinity of the existing house and within steeply sloping areas, is not recommended and should be avoided. However, if necessary, hammering should be carried out horizontally along bedding planes of pre-cut rock boulders where possible with vibration and noise limits restricted to those acceptable to the existing buildings and comfortable to residents within the adjoining properties.

Induced vibrations in structures adjacent to the excavation should not exceed a Peak Particle Velocity (PPV) of 10mm/sec for brick or unreinforced structures in good condition, 5mm/sec for residential and low rise buildings or 2mm/sec for historical or structures in sensitive conditions. It is recommended that monitoring is carried out during excavation using a vibration monitoring instrument (seismograph) and alarm levels (being the appropriate PPV) selected in accordance with the type of structures present within the zone of influence of the proposed excavation.

If vibrations are considered to be possible during construction due to the use of heavy ripping and rock hammers, it is recommended a dilapidation survey of the existing buildings within the site and adjoining infrastructure. If vibrations in adjacent structures exceed the above values or appear excessive during construction, excavation should cease and the project Geotechnical Practitioner should be contacted immediately for appropriate reviews.

Preparation of dilapidation survey report and vibration monitoring plan together with vibration monitoring during rock excavation should constitute as “Hold Points”.

8.5 Preliminary Landslide Risk Assessment

8.5.1 General

The site is categorised as “Landslip Risk Class H1” as depicted on the Pittwater Council Geotechnical Hazard Map (Reference 8). According to information provided in the Pittwater Council website, Hazard Zone H1 represents geotechnical hazards with the highest likelihood of occurrence. The information also indicates H1 zone is where the

level of likelihood of instability is assessed to be Level A, B or C, which are described as "Almost Certain", "Likely" and "Possible", respectively, likelihood.

Therefore, geotechnical investigation and assessment in accordance with guidelines published by The Australian Geomechanics Society (Reference 1) is required for this site in order to demonstrate the proposed development is justified in terms of geotechnical stability.

The Australian Geomechanics Society (AGS) recommends the landslide risk of a site be assessed on the basis of the likelihood of a landslide event and the consequences of that event. The guidelines on qualitative measures for the likelihood and consequence of landslides and assumed level of risk are provided in Reference 1.

In this section the stability of the site before and after construction of the proposed development are assessed based on the AGS guidelines, as a preliminary assessment.

8.5.2 Zones A and C

Minor earthworks are expected to be required in order to create building platforms suitable for the proposed building platforms and subdivision roads and driveways within the geomorphic zones A and C. Earthworks are expected to consist of cutting within the relatively elevated areas and filling within the relatively low elevation areas. Since the ground is gently sloping and there will be minor earthworks, the potential for instability risks for these zones would be very low and hence no landslide risk assessment is required at this stage.

8.5.3 Zone B - Predevelopment

The stability of a site is generally governed by site factors such as slope angles, water movements and drainage, depth of insitu soils, and strength of sub-surface material.

Examination of the existing conditions within the site did not indicate obvious significant signs of mass instability or incipient instability. However, some signs of localised and minor soil creep were observed on the steeply sloping portion of Zone B and the presence of rock boulders scattered within the site indicates previous rock movement in the past.

The existing trees are assessed to be contributing to the site stability due to root effects on stabilising the soil layers overlying the bedrock.

Due to the presence of fill, alluvial and colluvial soils as well as boulders within the moderately to steeply sloping portions of Zone B, the following hazards have been identified as potential at the existing conditions:

- Soil creep associated with fill, alluvial and colluvial soils;
- Deep seated and shallow landslide; and
- Rock boulder rolling.

The assessed risk levels of the hazards at the existing conditions are summarised in Table 2. In the assessment consideration was given to the potential effects of instability on the existing house and adjoining infrastructure, including effects on the land, buildings and occupiers/users.

Table 2: Assessed Risk to Property – Predevelopment (Preliminary)

Potential Hazard	Qualitative Measures of Likelihood	Qualitative Measures of Consequences to Property	Qualitative Risk Analysis – Level of Risk to Property
Creep of fill, alluvial and colluvial soils	C – Possible (10^{-3}) to D – Unlikely (10^{-4})	4: Minor 5%	Moderate to Low
Deep seated and shallow landslide	C – Possible (10^{-3}) to D – Unlikely (10^{-4})	3: Medium 20%	Moderate to Low
Rock boulder rolling	C – Possible (10^{-3}) to D – Unlikely (10^{-4})	3: Medium 20%	Moderate to Low

The overall slope instability risk associated with the Zone B under existing conditions prior to construction of the currently proposed development is assessed to be **"Moderate to Low"** resulting from down slope soil creep, potential deep seated landslide and rock boulder rolling. According to AGS 2007c, the "Moderate Risk Level" may be tolerated in certain circumstances but requires investigations, planning and implementation of treatment options to reduce the risk to "Low Risk Level". Detailed investigation, planning and implementation of treatment options are required to reduce risk to Low. The "Low

Risk Level" is usually acceptable to regulators. It is the level where ongoing maintenance is required if treatment has been implemented to reduce the risk to this level.

In accordance with the AGS guidelines the annual probability of risk to life ($R_{(LoL)}$) for the person most at risk pre-development due to the hazards listed in Table is assessed to be in the order of 1×10^{-4} to 1×10^{-5}/annum. The AGS guidelines recommend tolerable loss of life risk for the person most at risk for the "existing slopes" is 1×10^{-4}/annum.

8.5.4 Zone B - Post-Development

Provided drawings of the subdivision plan and available information on the proposed development indicate the following main construction activities:

- Earthworks consisting of cut and fill for preparation of the proposed building platforms and access driveways within the residential lots;
- Earthworks consisting of cut and fill for preparation of the proposed subdivision roads/access driveways;
- Excavations within the proposed basements within the lots located with geomorphic Zone B that is designated by Aargus; and
- Trenching for the proposed underground services.

It is assessed that if not carefully implemented or constructed in stages the above activities with reference to the "Moderate to Low Risk" of landslide at the site existing conditions within Zone B may lead to a potential for increase in the likelihood of landslide occurrence within the site. Therefore, appropriate measures to mitigate against landslide risk should be incorporated into the design and construction of the proposed development, specifically into the design and construction of earthworks, retaining walls and foundations. The mitigation and control measures recommended for the proposed development are summarised in Section 8.5.5 of this report.

On the condition that the recommendations and design parameters provided in this report are taken into consideration during design and construction as well as post construction, the recommendations summarised in Section 8.5.5 in particular, the assessed risks relating to stability of the site at completion of construction of the foundations and retaining walls are summarised in Table 3.

Table 3: Assessed Risk to Property – Post-development (Preliminary) based on Aargus Recommendations

Potential Hazard	Qualitative Measures of Likelihood	Qualitative Measures of Consequences to Property	Qualitative Risk Analysis – Level of Risk to Property
Creep of fill, alluvial and colluvial soils	D – Unlikely 10^{-4}	4:Minor 5%	Low
Deep seated and shallow landslide	D – Unlikely 10^{-4}	3: Medium 20%	Low
Rock boulder rolling	D – Unlikely 10^{-4}	3: Medium 20%	Low

The overall slope instability risk associated with the site post construction of the currently proposed development is assessed to be **"Low"** resulting from activities within the site of proposed development based on design and construction of the development to be in accordance with Aargus recommendations**.**

The risk to life for the person most at risk post-development due to the above listed hazards is assessed to be less than 1 x 10^{-5}/annum. The AGS guidelines recommend tolerable loss of life risk for the person most at risk for the "new constructed slopes/new development" is 1 x 10^{-5}/annum. The risk to life during construction on crews has not been assessed as it is not part of scope of this investigation and it should be assessed during the "Construction Certificate" stage of the development depending on the construction methodology proposed for this development.

8.5.5 Mitigation and Control Measures

To reduce the level of risk of instability within geomorphic Zone B designated by Aargus, the proposed development at this site should be constructed according to the recommendations presented in this report together with following provisions:

- In general, the design and construction of earthworks, foundations, retaining structures, excavation stabilisation and drainage measure for the proposed development should adhere to good engineering practice for hillside construction as set out in Appendix G of AGS 2007c guidelines (Appendix I).
- The design and construction of the ground structures of the proposed development are carried out taking into consideration the recommendations and parameters provided in this report.

- Proposed excavations within the site should be carried out in staged manner, as recommended in this report and be accompanied by site observations by a Geotechnical Practitioner and monitoring for ground movement and vibration.
- Installation of suitable shoring systems prior to excavation of basements, such as line of equally spaced bored cast insitu reinforced concrete piles sufficiently socketed into the underlying bedrock is assessed to be suitable for providing temporary and permanent retention of the excavated ground. Alternatively temporary batter slope may be applicable with slope ratios of 1V:3H for cuts in fill, alluvial and colluvial soils and 1V:2H for cuts in very stiff residual soils and weathered rock. Steeper batter slopes will likely require stabilisation with soil nailing in conjunction with the use of reinforced shotcrete.
- Any vertical cut or fill exceeding 0.5m in depth should be retained by appropriately designed retaining walls.
- No filling should be undertaken within 6.0m of the break of slope.
- Vibration levels should be monitored if methods of excavation adopted for excavation are likely to produce vibration intensities that may be detrimental to existing structures or triggering instability in the soils and rock within the site.
- Appropriate drainage measures should be incorporated to ensure all surface and subsurface water flows are removed from the site and surrounding affected areas.
- Retaining walls should be constructed and supported in such a manner as not to induce stability issues that may be associated with construction procedures and sequencing or exposure of faces to be supported.
- Backfills behind walls within the development area should be placed and compacted to engineering standards in accordance with Australian Standard AS3798-2007 (Reference 6), which provides the criteria for earthworks associated with residential developments, including materials, compaction criteria, site preparation and fill construction, methods of testing and inspection and testing frequencies. Appropriate backfill drainage is to be provided.
- Foundation systems for the building structures and retaining walls, for the residential lots and driveways within Zone B in particular, are to be founded and embedded into competent soils and rock horizons, and designed for lateral earth pressures induced by potential of soil creep movement.

- Protective measures against rolling of rock boulders from the upper slope of Zone B should be provided such as rock boulder removal, stabilising by meshing and rock bolting, building rock-fall barriers or catch fences or breaking rock boulders into smaller size and more angular shape before removal.
- Existing trees should be maintained as they are assessed to be contributing to the site stability.
- Inspection and maintenance on the retaining walls should be carried out periodically.
- Site specific geotechnical investigation will be required for each residential lot at the Construction Certificate stage based on details of the proposed development in order to confirm the actual stratification of the soils and rock horizons underlying each lot and preliminary landslide risk assessment provided in this report.
- Construction activities should be carefully planned and be observed by a Geotechnical Practitioner for further assessment of the necessary mitigation and control measures.
- Implementation of the measures recommended above should constitute as "Hold Points".

Should the above provisions and recommendations made in this report be taken into consideration in design and construction of the proposed development with Zone B as well as zones A and C, the level of risk of the overall instability of the proposed lots and driveways, may be considered to be reduced to normally acceptable levels.

8.6 Earth Retaining Structures and Anchors

Earth retaining structures, such as basement walls, temporary shoring walls and road retaining walls, should be designed to withstand the lateral earth, hydrostatic and earthquake (if applicable) pressures, and the applied surcharge loads in their zone of influence, including existing or proposed structures, traffic and construction related activities.

For the design of flexible retaining structures, where some lateral movement is acceptable, it is recommended the design should be based on active lateral earth pressure. Should it be

critical to limit the horizontal deformation of a retaining structure, the use of an earth pressure coefficient "At Rest" should be considered.

Recommended parameters for the design of earth retaining structures in the soils and rock horizons underlying the site are presented in Table 4.

Table 4: Preliminary Geotechnical Design Parameters for Retaining Walls

Unit	Unit Weight γ (kN/m^3)	Effective Cohesion c' (kPa)	Effective Internal Friction Angle ϕ' (degrees)	Modulus of Elasticity $E_{s,h}$ (MPa)	Poisson's Ratio ν
Fill (majority of VL-MD silty Sand)	17	0	26	8	0.35
Alluvial/ Colluvial S-F Clay, L-MD Sand	17	0	26	8	0.35
Residual VSt sandy Clay, D clayey Sand	19	8	26	15	0.35
H-Ex low strength, CW-EW Sandstone, Siltstone or Shale	20	10	28	38	0.3
Class V Sandstone	22	35	35	75	0.3
S=Soft, F=Firm, St=Stiff, VSt=Very Stiff, H=Hard, VL= Very Loose, L=Loose, MD=Medium Dense, D=Dense, CW=Completely Weathered, EW=Extremely Weathered					

Table 5 provides preliminary coefficients of lateral earth pressure for the soils and rock horizons encountered during the geotechnical site investigation or horizons inferred to be present underlying the site. The coefficients provided are based on horizontal ground surface and fully drained conditions.

Table 5: Preliminary Coefficients of Lateral Earth Pressure

Unit	Coefficient of Active Lateral Earth Pressure Ka	Coefficient of Lateral Earth Pressure "At Rest" Ko	Coefficient of Passive Lateral Earth Pressure Kp
Fill (majority of VL-MD silty Sand)	0.39	0.56	2.56
Alluvial/ Colluvial S-F Clay, L-MD Sand	0.39	0.56	2.56
Residual VSt sandy Clay, D clayey Sand	0.39	0.56	2.56
H-Ex low strength, CW-EW Sandstone, Siltstone or Shale	0.36	0.53	2.77
Class V Sandstone	0.27	0.43	3.69

- Coefficient of active and passive lateral earth pressure Ka and Kp, respectively, can be calculated using Rankine's or Coulomb's equations as appropriate.
- Coefficient of lateral earth pressure At Rest Ko, can be calculated using Jacky's equation.

The coefficients of lateral earth pressure should be verified by the project structural engineer prior to use in the design of retaining walls. Simplified calculations of lateral active (or At Rest) and passive earth pressures can be carried out using the following Rankine equations:

$Pa = K\,\gamma\,H - 2c\sqrt{K}$ For calculation of Lateral Active or At Rest Earth Pressure

$Pp = K_p\,\gamma\,H + 2c\sqrt{K_p}$ For calculation of Passive Earth Pressure

Where;

P_a = Active (or At Rest) Earth Pressure (kN/m^2)
P_p = Passive Earth Pressure (kN/m^2)
γ = Bulk density (kN/m^3)
K = Coefficient of Earth Pressure (K_a or K_o)
Kp = Coefficient of Passive Earth Pressure
H = Retained height (m)
c = Effective Cohesion (kN/m^2)

Temporary anchors will require embedment in competent Class V Sandstone or better. An allowable bond stress of 100kPa may be adopted for temporary anchors within Class V Sandstone.

Anchors should undergo proof testing following installation. The anchors can be designed for the parameters recommended above providing:

- The bond (socket) length in Class V Sandstone or better at least 3.0m; and
- Anchors are proof tested to 1.3 times the design working load specified by the structural engineer, before they are locked off at working load. Anchor testing should constitute as a "Hold Point".

Site specific geotechnical investigation will be required for each residential lot at the Construction Certificate stage based on the design configuration of walls in order to confirm the actual stratification of the soils and rock horizons underlying each lot and their engineering parameters.

8.7 Foundations

If sufficiently embedded in natural soils being residual soils or weathered sandstone, the proposed residential dwellings within Zone A can be supported by shallow foundation system consisting of pad or strip footings and/or raft slab on grade with thickened slab under columns and walls.

Preparation of the proposed building platforms within Zone B is expected to involve excavation to create the basement levels and possibly minor filling to create level ground on the downslope sides of the platforms. Shallow foundation systems similar to Zone A may also be applicable in general if sufficiently embedded in residual soils or weathered sandstone. Installation of piles may be required in areas of fill, where building platforms are located within steeply sloping areas or where there is a potential for downslope creep.

Due to the presence of alluvial soils to approximately 2.0m bgl, underlain by residual soils extending in depth to the top of bedrock, which is at or below approximately 6.5 m bgl the proposed residential building with Zone C is expected to require a piled foundation system. The piles should be installed through all fill, alluvial, residual soils and embedded either in

the underlying residual soils or in the weathered bedrock. Suitable pile options include the following:

- Cast in situ reinforced concrete bored piles.
- Steel Screw Piles.

Feasibility of options recommended for each zone above should be carefully assessed for each lot and detail design of the foundations to be carried out taking into consideration all possible loading and geotechnical design scenarios. Table 6 provides preliminary geotechnical allowable capacities and parameters recommended for design of foundations embedded in materials encountered in the boreholes or inferred to be present underlying the site.

Table 6: Preliminary Geotechnical Foundation Design Capacities and Parameters

Unit	Allowable End Bearing Capacity (kPa)[1]	Allowable Shaft Adhesion Compression (Tension) (kPa)[2]	Elastic Modulus (Vertical) (MPa)
Fill (majority of VL-MD silty Sand)	Not Recommended	Not Recommended	10
Alluvial/ Colluvial S-F Clay, L-MD Sand	Not Recommended	Not Recommended	10
Residual VSt sandy Clay, D clayey Sand	100 Shallow Footings 175 Piles	20 (10)	20
H-Ex low strength, CW-EW Sandstone, Siltstone or Shale	200 Shallow Footings 350 Piles	50 (25)	50
Class V Sandstone	1000	100 (50)	100

[1] With a minimum embedment depth of 0.3m into the relevant bearing stratum for shallow foundations and 0.5m for deep foundations.
[2] Clean rock socket of roughness of at least grooves of depth 1mm to 4mm and width greater than 5mm at spacing of 50mm to 200mm. Shaft Adhesion is applicable to piles only.

Shallow foundations can be designed in accordance Australian Standard AS 2870-2011 (Reference 4) and pile foundations can be designed in accordance with Australian Standard AS 2159-2009 (Reference 3). Screw piles are usually designed, constructed and certified by specialist screw-piling contractors.

To minimise the effects of differential settlement under the building loads, it is recommended all foundations should be founded on consistent, natural insitu soils of similar consistency or rock of similar class.

Resistance against uplift forces can be typically provided by the mass and embedment depth of shallow footing. Alternatively, piles can be used to provide the uplift resistance required. Recommended shaft adhesion parameters for tension are provided in Table 6.

For bored piles shaft adhesion should be reduced or ignored within pile sockets lengths that are smeared and fail to satisfy cleanliness requirements. Where the footings penetrate soils that are susceptible to shrinkage and swelling, we recommend that the shaft adhesion be ignored in the zone of seasonal moisture variations due to the potential of shrinkage cracking.

Should groundwater flow, seepages or surface runoff be encountered within foundation excavations, the excavations should be dewatered prior to concrete placement or appropriate underwater placement techniques should be adopted. Any loose debris and wet soils should also be removed from excavations.

Shallow or piled foundation systems should be designed taking into consideration the site classification.

Site specific geotechnical investigation will be required for each residential lot, particularly for lots within Zone B, at the Construction Certificate stage based on details of the proposed development in order to confirm the actual stratification of the soils and rock horizons underlying each lot, the appropriate foundation systems and the available bearing capacity.

An experienced Geotechnical Practitioner should inspect foundation excavations to ensure the foundation bases have been taken to suitable materials of appropriate bearing capacity.

8.8 Drainage

The site investigation was undertaken during a relatively dry period. Possible seepages may be encountered at the soil rock interface during rainy periods and suitably designed

drainage and waterproofing measures should be installed for the proposed residential lots and driveways where significant excavation will be required.

Zones A

Due to the relatively deep groundwater levels within Zone A and the anticipated relatively shallow depth of foundation excavations within this zone, the potential effects of groundwater on the proposed development are assessed to be low.

Zone B

The discharge of water on the steep ground within Zone B represents a geotechnical hazard and increases the potential for landslide. Measures for management of surface runoff should be considered for construction of the proposed residential lots and driveways. Permanent measures to control drainage behind retaining and basement walls should be also provided. Flexible pipes with movement joints should be used for all drainage including stormwater pipes to cater for potential soil movement, which could damage rigid pipes.

Drainage should be provided on the top of batter slopes of cuts and fill as well as retaining walls. This will enable diversion of runoff away from the slope face and behind the walls and reduces the potential for built up of hydrostatic pressures. Surface drainage should be able to discharge all stormwater within the site catchment to the roadside stormwater drains.

Additional drainage measures that may be suitable for sloping grounds, which will require confirmation during construction, include counterfort drains and bored drains, which are suitable for sites where seepage is significant. However, these measures are not considered required for the proposed residential lots within Zone B at this stage.

Zone C

The results of the geotechnical site investigation indicated possible seepage within the residual clays at depths of greater than 3.0m. Due to the relatively deep groundwater levels within Zone C and limited possible excavation for bored pits within this zone, the potential effects of groundwater on the proposed development are assessed to be low. However,

being located at the toe of the sloping grounds of Zone B installation of measures to control and divert surface runoff away from the residential lots within this zone will be required.

8.9 Preliminary Comments for Pavement Design Requirements

Laboratory testing on two samples obtained from the boreholes positioned within the proposed driveway alignment indicated CBR values ranging from 60% to 70%. However, the correlated CBR values based on results of DCP testing carried out at 6 locations away from proposed driveways indicated generally lower CBR values.

The correlated CBR Median value of the subgrade for the driveway alignments, below the topsoil, assuming saturated ground conditions generally ranged from 4% to 8%. The lowest values of 4% encountered in DCP1 and DCP4 within areas underlain by hillwash and alluvial soils.

Topsoil and any deleterious material that may be encountered within the alignments of the proposed roads should be removed prior to pavement construction. Any loose or soft to firm materials that may be present, the existing fill and weak alluvial soils in particular, as confirmed by inspection and insitu testing, should be either removed or improved by compaction in order to increase the strength of the material.

Pavements underlain by compacted fill and the alluvial soils can be designed based on a CBR value of 3%. A CBR value of 8% may be adopted for pavements underlain by very stiff residual soils, or compacted/improved fill and alluvial soils subject to confirmation by testing during construction.

The final levels of the subgrade, particularly in the areas between the locations of the boreholes positioned along the road alignment during this investigation should be inspected by an experienced Geotechnical Practitioner familiar with the contents of this report in order to confirm the design CBR values recommended in this report. Pavement design should be complemented by the provision of adequate surface and subsurface drainage.

8.10 Preliminary Site Earthquake Classification

The results of the site investigation indicated the presence of fill, alluvial and residual soils extending to depths varying from approximately 1.0m to 6.5m bgl or deeper. In

accordance with Australian Standard AS 1170.4-2007 (Reference 5) the site may be classified as a "Shallow soil site" (Class C_e) for design of foundations and retaining walls embedded in the underlying soils and completely weathered sandstone. The Hazard Factor (Z) for Sydney in accordance with AS 1170.4-2007 is considered to be 0.08.

9. CONCLUSIONS AND RECOMMENDATIONS

For the purpose of this geotechnical report, Aargus divided the site into three geomorphic zones being Zone A, Zone B and Zone C. These zones were designated based on the existing topography and the underlying soils encountered during the site investigation. Zone A is the reasonably flat and gently sloping area within the elevated hilltop area and Zone B is the moderately to steeply sloping ground below and surrounding Zone A. Zone C is relatively very narrow and short strip of reasonably level ground at the toe of Zone B, within the site northern corner, which is underlain by shallow alluvial deposits.

The results of the geotechnical site investigation and assessment for this site indicate the ground conditions in general are suitable for the proposed subdivision development within the three zones designated by Aargus subject to adoption of the recommendations made in Section 8 of this report.

Site specific geotechnical investigation will be required for each residential lot, particularly for lots within Zone B, at the Construction Certificate stage based on details of the proposed development in order to confirm the actual stratification of the soils and rock horizons underlying each lot and the assessments and recommendations provided in this report.

It is recommended the final construction drawings be reviewed by a Geotechnical Practitioner for site specific assessment and confirmation of the suitability of the ground structures and drainage measures of the proposed development.

Observations by a Geotechnical Practitioner familiar with the contents of this report will be required during construction of the proposed development. The observations should be considered as "Hold Points" to be nominated for construction of the ground structures and drainage measures.

10. LIMITATIONS

The geotechnical assessment of the subsurface profile and geotechnical conditions within the proposed development area and the conclusions and recommendations presented in this report have been based on available information obtained during the work carried out by Aargus and in the provided documents listed in Section 2 of this report. Inferences about the nature and continuity of ground conditions away from and beyond the locations of field exploratory tests are made, but cannot be guaranteed.

It is recommended that should ground conditions including subsurface and groundwater conditions, encountered during construction and excavation vary substantially from those presented within this report, Aargus Pty Ltd be contacted immediately for further advice and any necessary review of recommendations. Aargus does not accept any liability for site conditions not observed or accessible during the time of the inspection.

This report and associated documentation and the information herein have been prepared solely for the use of **DEP (Warriewood No. 2) Pty Ltd** and any reliance assumed by third parties on this report shall be at such parties' own risk. Any ensuing liability resulting from use of the report by third parties cannot be transferred to Aargus Pty Ltd, directors or employees.

The conclusions and recommendations of this report should be read in conjunction with the entire report.

For and on behalf of
Aargus Pty Ltd

David Forbes
BSc,(Geol) MAEG
Principal Engineering Geologist

Reviewed by

Mark Kiryakos
BScEng MEngSt
Technical Director
National Engineering Manager

APPENDIX A

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL REPORT

Aargus

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL ENGINEERING REPORT

More construction problems are caused by site subsurface conditions than any other factor. As troublesome as subsurface problems can be, their frequency and extent have been lessened considerably in recent years, due in large measure to programs and publications of ASFE/ The Association of Engineering Firms Practicing in the Geosciences.

The following suggestions and observations are offered to help you reduce the geotechnical-related delays, cost-overruns and other costly headaches that can occur during a construction project.

A GEOTECHNICAL ENGINEERING REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

A geotechnical engineering report is based on a subsurface exploration plan designed to incorporate a unique set of project-specific factors. These typically include the general nature of the structure involved, its size and configuration, the location of the structure on the site and its orientation, physical concomitants such as access roads, parking lots, and underground utilities, and the level of additional risk which the client assumed by virtue of limitations imposed upon the exploratory program.

To help avoid costly problems, consult the geotechnical engineer to determine how any factors which change subsequent to the date of the report may affect its recommendations.

Unless your consulting geotechnical engineer indicates otherwise, *your geotechnical engineering report should NOT be used:*

- when the nature of the proposed structure is changed: for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an un-refrigerated one,
- when the size or configuration of the proposed structure is altered,
- when the location or orientation of the proposed structure is modified,
- when there is a change of ownership, or

for application to an adjacent site.

Geotechnical engineers cannot accept responsibility for problems which may develop if they are not consulted after factors considered in their report's development have changed.

Geotechnical reports present the results of investigations carried out for a specific project and usually for a specific phase of the project. The report may not be relevant for other phases of the project, or where project details change.

The advice herein relates only to this project and the scope of works provided by the Client.

Soil and Rock Descriptions are based on AS1726-1993, using visual and tactile assessment except at discrete locations where field and/or laboratory tests have been carried out. Refer to the attached terms and symbols sheets for definitions.

MOST GEOTECHNICAL "FINDINGS" ARE PROFESSIONAL ESTIMATES

Site exploration identifies actual subsurface conditions only at those points where samples are taken, when they are taken. Data derived through sampling and subsequent laboratory testing are extrapolated by geotechnical engineers who then render an opinion about overall subsurface conditions, their likely reaction to proposed construction activity, and appropriate foundation design. Even under optimal circumstances actual conditions may differ from those inferred to exist, because no geotechnical engineer, no matter how

qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than a report indicates. Actual conditions in areas not sampled may differ from predictions. *Nothing can be done to prevent the unanticipated, but steps can be taken to help minimize their impact. For this reason, most experienced owners retain their geotechnical consultants through the construction stage,* to identify variances, conduct additional tests which may be needed, and to recommend solutions to problems encountered on site.

SUBSURFACE CONDITIONS CAN CHANGE

Subsurface conditions may be modified by constantly changing natural forces. Because a geotechnical engineering report is based on conditions which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time.* Speak with the geotechnical consultant to learn if additional tests are advisable before construction starts.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions, and thus, the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

Subsurface conditions can change with time and can vary between test locations. Construction activities at or adjacent to the site and natural events such as flood, earthquake or groundwater fluctuations can also affect the subsurface conditions.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND PERSONS

Geotechnical engineers' reports are prepared to meet the specific needs of specific individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor, or even some other consulting civil engineer. Unless indicated otherwise, this report was prepared expressly for the client involved and expressly for purposes indicated by the client. Use by any other persons for any purpose, or by the client for a different purpose, may result in problems.
No individual other than the client should apply this report for its intended purpose without first conferring with the geotechnical engineer. No person should apply this report for any purpose other than that originally contemplated without first conferring with the geotechnical engineer.

A GEOTECHNICAL ENGINEERING REPORT IS SUBJECT TO MISINTERPRETATION

Costly problems can occur when other design professional develop their plans based on misinterpretations of a geotechnical engineering report. To help avoid these problems, the geotechnical engineer should be retained to work with other appropriate design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to geotechnical issues.

The interpretation of the discussion and recommendations contained in this report are based on extrapolation/interpretation from data obtained at discrete locations. Actual conditions in areas not sampled or investigated may differ from those predicted

BORING LOGS SHOULD NOT BE SEPARATED FROM THE ENGINEERING REPORT

Final boring logs are developed by geotechnical engineers based upon their interpretation of field logs (assembled by site personnel) and laboratory evaluation of field samples. Only final boring logs customarily are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings because drafters may commit errors or omissions in the

transfer process. Although photographic reproduction eliminates this problem, it does nothing to minimize the possibility of contractors misinterpreting the logs during bid preparation. When this occurs, delays, disputes and unanticipated costs are the all-too-frequent result.

To minimise the likelihood of boring log misinterpretation, give contractors ready access in the complete geotechnical engineering report prepared or authorized for their use. Those who do not provide such access may proceed under mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes which aggravate them to disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY

Because geotechnical engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against geotechnical consultants. To help prevent this problem, geotechnical engineers have developed model clauses for use in written transmittals. These are not exculpatory clauses designed to foist geotechnical engineers' liabilities onto someone else. Rather, they are definitive clauses which identify where geotechnical engineers' responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your geotechnical engineering report, and you are encouraged to read them closely. Your geotechnical engineer will be pleased to give full and frank answers to your questions.

OTHER STEPS YOU CAN TAKE TO REDUCE RISK

Your consulting geotechnical engineer will be pleased to discuss other techniques which can be employed to mitigate risk. In addition, ASFE has developed a variety of materials which may be beneficial. Contact ASFE for a complimentary copy of its publications directory.

FURTHER GENERAL NOTES

Groundwater levels indicated on the logs are taken at the time of measurement and may not reflect the actual groundwater levels at those specific locations. It should be noted that groundwater levels can fluctuate due to seasonal and tidal activities.

APPENDIX B

SITE PLAN (FIGURE 1)

Aargus

Image Source ""Plan showing Detail and Levels at 1 Fern Creek Rd, Warriewood being Lots 1 to 17 in DP270922 Northern Beaches LGA" by YSCO Geomatics Land Resource Consultants, Ref. No. 0422/1, issued Feb 2022.

Aargus ENVIRONMENTAL - ENGINEERING - DRILLING - LABORATORIES - ASBESTOS

Drawn	RF	**DEP (Warriewood No. 2) Pty Ltd Geotechnical Investigation No. 1 Fern Creek Road, Warriewood NSW 2102**	Aargus	Figure	**1**
Checked	RF			Title	**Updated Site Plan**
Date	20th February 2023			Job No	**GS5895-2B**
Scale @ A3	NTS				

APPENDIX C

SITE PHOTOGRAPHS (FIGURES 2, 3)

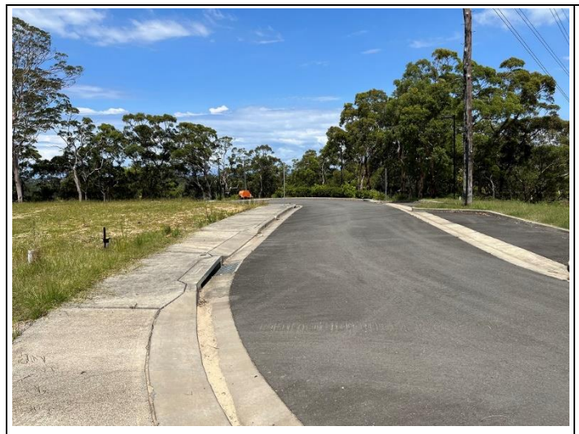
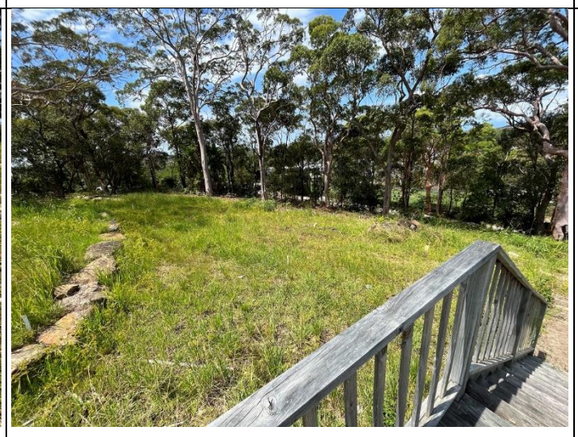
			
Photograph 1 Knight Street near the dead-end looking SW	**Photograph 2** View looking west across Lots 14 (front) and 13 (rear)	**Photograph 3** View looking NE across Lots 13 (left), 14 (right) and 12 (at the back) towards houses on Cherry Lane	**Photograph 4** View from Lot 16 north across Lots 8 and 15, with Lots 9, 10, 11 behind
			
Photograph 5 Looking North across Lot 16 and Lot 8. Lot 16 is now vacant, the house previously present is removed.	**Photograph 6** Looking NE across Lots 6 and 7	**Photograph 7** Looking SE across the top of Lots 4 and 5 from the edge of Knight St. Some trees appear to be removed from this area, probably to allow construction of the retaining wall to support the road.	**Photograph 8** View looking south across Lot 5 from Knight Street

Figure 2 – Site Photographs

			
Photograph 9 Looking south across Lot 4	**Photograph 10** View looking south-west across Lots 3 (right) and 2 (left) towards the intersection of Orchard Street and Knight Street	**Photograph 11** View looking west across Lots 3 (left) and 17 (right)	

Figure 3 – Site Photographs

APPENDIX D

ENGINEERING BOREHOLE LOGS

Aargus

Aargus Pty Ltd
446 Parramatta Road
Petersham New South Wales 2049
Telephone: (04)1829-1497

BOREHOLE NUMBER BH1

CLIENT DEP (Warriewood No. 2) Pty Ltd **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER GS5895/2A **PROJECT LOCATION** No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 01/07/14 **COMPLETED** 01/07/14 **R.L. SURFACE** 25.86 **DATUM** m AHD

DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1

HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF

NOTES RL top of borehole is approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
ADV						TOPSOIL, silty fine to medium SAND, grey brown, dry to moist, medium dense, friable.		TOPSOIL
						SAND, orange and orange brown, moist, dense.	DS	RESIDUAL SOIL
						traces of orange clay from 0.5m bgl.	SPT 2, 6, 20 N=26	
		25				becoming friable, non plastic from 0.8m bgl.		
			1			SANDSTONE, fine to medium grained, orange, extremely to highly weathered, low strength.		BEDROCK
ADT						becoming light brown, friable, extremely to highly weathered sandstone from 1.4m bgl.		'V' Bit Refusal at 1.5m bgl.
		24						
			2			hard drilling from 2.1m bgl.		'TC' Bit Refusal at 2.2m bgl.
	NOT ENCOUNTERED					Borehole BH1 terminated at 2.2m		
		23	3					
		22	4					
		21	5					
		20	6					

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Petersham New South Wales 2049
Telephone: (04)1829-1497

BOREHOLE NUMBER BH2

CLIENT DEP (Warriewood No. 2) Pty Ltd
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER GS5895/2A
PROJECT LOCATION No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 01/07/14 **COMPLETED** 01/07/14 **R.L. SURFACE** 30.05 **DATUM** m AHD
DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---
EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1
HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF
NOTES RL top of borehole is approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
ADV	NOT ENCOUNTERED					TOPSOIL, silty fine to medium SAND, with some highly weathered sandstone fragments, grey brown, dry to moist, loose to very dense.		TOPSOIL
ADT		29	1			SANDSTONE, highly to moderately weathered, low to medium strength, red brown, fine to medium grained.		BEDROCK 'V' Bit Refusal at 0.8m bgl.
		28	2			Borehole BH2 terminated at 1.5m		'TC' Bit Refusal at 1.5m bgl.
		27	3					
		26	4					
		25	5					
		24	6					

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BOREHOLE NUMBER BH3

CLIENT DEP (Warriewood No. 2) Pty Ltd
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER GS5895/2A
PROJECT LOCATION No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 01/07/14 **COMPLETED** 01/07/14 **R.L. SURFACE** 37.5 **DATUM** m AHD
DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---
EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1
HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF
NOTES RL top of borehole is approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
ADV		37	0			TOPSOIL/FILL, fine to coarse SAND, grey brown, friable, with some sandstone, highly weathered boulders, moist, loose.	DS	FILL
							DS	
			1			boulders at 0.8m bgl.		
						TOPSOIL, fine to coarse SAND, grey brown, friable, moist, medium dense.	SPT 18, 9, 11 N=20	BEDROCK
						SANDSTONE, highly weathered, low strength, orange and red brown, possible boulders.		
		36				SANDSTONE, extremely to highly weathered, very low to low strength, orange.		
			2				DS	
ADT	NOT ENCOUNTERED	35						'V' Bit Refusal at 2.2m bgl
			3			becoming very slightly clayey, dark orange from 3.0m bgl.	DS	
		34						'TC' Bit Refusal at 3.9m bgl
			4			Borehole BH3 terminated at 3.9m		
		33						
			5					
		32						
			6					
		31						

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BOREHOLE NUMBER BH4

CLIENT DEP (Warriewood No. 2) Pty Ltd
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER GS5895/2A
PROJECT LOCATION No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 02/07/14 **COMPLETED** 02/07/14 **R.L. SURFACE** 33.2 **DATUM** m AHD
DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---
EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1
HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF
NOTES RL top of borehole is approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
ADV	NOT ENCOUNTERED	33				TOPSOIL, fine to medium silty SAND, friable, dry to moist, loose.		TOPSOIL
						Silty SAND, fine to medium grained, grey brown, friable, moist, loose to medium dense.		RESIDUAL SOIL
							SPT 6, 7, 9 N=16	
			1			Silty SAND, fine to medium grained, non plastic, orange, with residual sandstone, moist, very dense.		
ADT		32						'V' Bit Refusal at 1.5m bgl
								'TC' Bit Refusal at 1.8m bgl
						Borehole BH4 continued as cored hole		
			2					
		31						
			3					
		30						
			4					
		29						
			5					
		28						
			6					
		27						

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BOREHOLE NUMBER BH4

CLIENT DEP (Warriewood No. 2) Pty Ltd **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER GS5895/2A **PROJECT LOCATION** No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 02/07/14 **COMPLETED** 02/07/14 **R.L. SURFACE** 33.2 **DATUM** m AHD

DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1

HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF

NOTES RL top of borehole is approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm (30 100 300 1000 3000)	Defect Description
		33									
			1								
		32			Continued from non-cored borehole						
NLMC			2		SANDSTONE, orange with light grey lamination, medium to high strength, moderately weathered.	MW					1.84m, joint, 5 deg, planar. 1.89m, joint, 5 deg, curve. 2.00m, joint, 30 deg, planar. 2.14m, bedding, 20 deg. 2.26m, bedding, 20 deg, EW, 1mm.
		31							28		
					SANDSTONE, orange with light grey lamination, very low to low strength, highly to extremely weathered.	HW/EW					2.40m, clay seam, 70-90 deg, 30mm.
			3		Sandy CLAY, with extremely weathered sandstone, orange, medium plasticity, very low strength.	EW			0		
		30									Continued as Augering from 3.2m to 3.6m bgl.
			4		BH4 terminated at 3.6m						
		29									
			5								
		28									
			6								
		27									

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BOREHOLE NUMBER BH5

CLIENT DEP (Warriewood No. 2) Pty Ltd **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER GS5895/2A **PROJECT LOCATION** No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 02/07/14 **COMPLETED** 02/07/14 **R.L. SURFACE** 36.1 **DATUM** m AHD

DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1

HOLE SIZE 450mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF

NOTES RL top of borehole is approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
REFUAL WITH 450mm AUGER.	NOT ENCOUNTERED	36				TOPSOIL, SAND, brown grey, fine grained, friable, traces of silt and rootlets.		TOPSOIL
						Silty SAND, grey brown, friable, non plastic, dry to moist, loose.		RESIDUAL SOIL
						Silty SAND, with highly weathered sandstone, rounded pebbles, dense.		Refusal of 450mm Diameter Auger at 0.6m bgl.
						Borehole BH5 terminated at 0.6m		
		35	1					
		34	2					
		33	3					
		32	4					
		31	5					
		30	6					

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BOREHOLE NUMBER BH6

CLIENT DEP (Warriewood No. 2) Pty Ltd
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER GS5895/2A
PROJECT LOCATION No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 02/07/14 **COMPLETED** 02/07/14 **R.L. SURFACE** 26 **DATUM** m AHD
DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---
EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1
HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF
NOTES RL top of borehole is approximate

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
ADV	NOT ENCOUNTERED						TOPSOIL/HILLWASH, silty SAND, non plastic, dry, loose.		TOPSOIL
						CL	Sandy CLAY, orange brown, medium plasticity, moist, stiff.		ALLUVIUM
			25	1			Silty CLAY, with fine sand, orange with dark red mottling, medium plasticity, very stiff.	SPT 3, 7, 9 N=16	
			24	2			becoming pale grey with pale red mottling from 2.0m bgl.		RESIDUAL SOILS
			23	3			becoming pale grey, hard from 3.2m bgl.		
			22	4					
			21	5					
			20	6			Borehole BH6 terminated at 6.5m		Minimal 'V' Bit Refual at 6.5m bgl

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BOREHOLE NUMBER BH7

CLIENT DEP (Warriewood No. 2) Pty Ltd
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER GS5895/2A
PROJECT LOCATION No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 02/07/14 **COMPLETED** 02/07/14 **R.L. SURFACE** 27.5 **DATUM** m AHD
DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---
EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1
HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF
NOTES RL top of borehole is approximate

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
ADV	NOT ENCOUNTERED		27				Silty SAND, non plastic, dry to moist, loose to medium dense.		TOPSOIL/HILLWASH
ADT			26	1			SANDSTONE, highly weathered, low strength, pale to dark orange.		'V' Bit Refusal at 0.9m bgl BEDROCK
			25	2			SANDSTONE, fine grained, highly weathered, reworked to Clayey SAND, low to medium plasticity, pale grey with pale red mottling, dry to moist, becoming pale red from 2.6m bgl.		Hard Drilling from 2.5m bgl. 'TC' Bit Refusal at 2.7m bgl
			24	3			Borehole BH7 continued as cored hole		
			23	4					
			22	5					
			21	6					

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Telephone: (04)1829-1497

BOREHOLE NUMBER BH7

CLIENT DEP (Warriewood No. 2) Pty Ltd
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER GS5895/2A
PROJECT LOCATION No. 1 Fern Creek Road, Warriewood NSW 2102

DATE STARTED 02/07/14 **COMPLETED** 02/07/14 **R.L. SURFACE** 27.5 **DATUM** m AHD
DRILLING CONTRACTOR BG Drilling Pty Ltd **SLOPE** 90° **BEARING** ---
EQUIPMENT Aargus Drilling Rig **HOLE LOCATION** Refer to Site Plan Figure 1
HOLE SIZE 100mm Diameter **LOGGED BY** DBF **CHECKED BY** DBF
NOTES RL top of borehole is approximate

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm (30 100 300 1000 3000)	Defect Description
			27	1								
			26	2								
			25			Continued from non-cored borehole						
NLMC				3		Clayey SAND, brown and grey, fine to medium grained, moist, very stiff to hard.	MW					
						SANDSTONE, grey, fine to medium grained, moderately weathered, very low strength.						
						Silt, grey, medium plasticity, moist, very stiff to hard.						
			24			SANDSTONE, grey with yellow mottling, extremely low strength, extremely weathered.	EW			38		3.56m, clayey sand seam, 40mm.
						reddish brown, very low strength, highly weathered, fine to coarse grained.	HW					
				4		grey, very low strength, moderately weathered, fine to medium grained.	MW					
						Silt, grey, medium plasticity, moist, very stiff to hard.						4.08m, sandy clay seam, 30mm.
			23			SANDSTONE, grey and brown, extremely low strength, highly weathered.	HW			48		
						Silt, grey, medium plasticity, moist, hard.						
				5		SHALE, dark grey with brown laminations, extremely low strength, highly weathered.	HW					5.37m, XW seam, 10mm.
			22									5.52m, XW seam, 10mm.
				6		BH7 terminated at 5.7m						
			21									

APPENDIX E

DCP TESTING RESULTS

PENETRATION RESISTANCE OF SOIL TEST FIELD SHEET

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Client:	DEP (Warriewood No.2) Pty Ltd	Test Type		Job No:	GS5895/2
Project:	Geotechnical Investigation			Date:	9/07/2014
Location:	No. 1 Fern Creek Road Warriewood. NSW, 2102.	DCP	■	Sheet:	1 of 1
		PSP		Test By:	MM

Depths (mm)	DCP No. 1	2	3	4	Depths (mm)	DCP No. 5	6		
0-100	3	7	5	1	0-100	3	4		
100-200	3	11	3	2	100-200	6	5		
200-300	4	5	4	6	200-300	12/50mm	7		
300-400	2	3	14	6	300-400	Bouncing	14/70mm		
400-500	2	3	Bouncing	13	400-500		Bouncing		
500-600	2	4		16	500-600				
600-700	3	6		11	600-700				
700-800	2	4		15	700-800				
800-900	4	5		Bouncing	800-900				
900-1000	5	7			900-1000				
1000-1100	Terminated	8			1000-1100				
1100-1200		9			1100-1200				
1200-1300		Bouncing			1200-1300				
1300-1400					1300-1400				
1400-1500					1400-1500				
1500-1600					1500-1600				
1600-1700					1600-1700				
1700-1800					1700-1800				
1800-1900					1800-1900				
1900-2000					1900-2000				
2000-2100					2000-2100				
2100-2200					2100-2200				
2200-2300					2200-2300				
2300-2400					2300-2400				
2400-2500					2400-2500				
2500-2600					2500-2600				
2600-2700					2600-2700				
2700-2800					2700-2800				
2800-2900					2800-2900				
2900-3000					2900-3000				
3000-3100					3000-3100				
3100-3200					3100-3200				
3200-3300					3200-3300				

APPENDIX F

LABORATORY TEST RESULTS

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Aargus Pty Ltd ACN: 050 212 710
Environmental - Remediation - Engineering - Laboratories - Drilling
446 Parramatta Road, Petersham NSW 2049
Ph: 1300 137 038 Fax: 1300 136 038

REPORT OF THE SOAKED C.B.R. OF A SOIL

CLIENT: DEP Warriewood No.2
PROJECT: Geotechnical Investigation
LOCATION: Fern Creek Rd, Warriewood

Job No. LS5895-2
Report No. N/A
Sample No. MT1
Date Sampled: 2/7/2014

Sampling Location: CBR1/BH9 On Site
Chainage: N/A

Sampling Methods: AS 1289 1.2.1 Clause 6.4 b

Depth of Sample: 0.2m-0.8m
Sample Description: Gravelly SAND- Brown/Grey

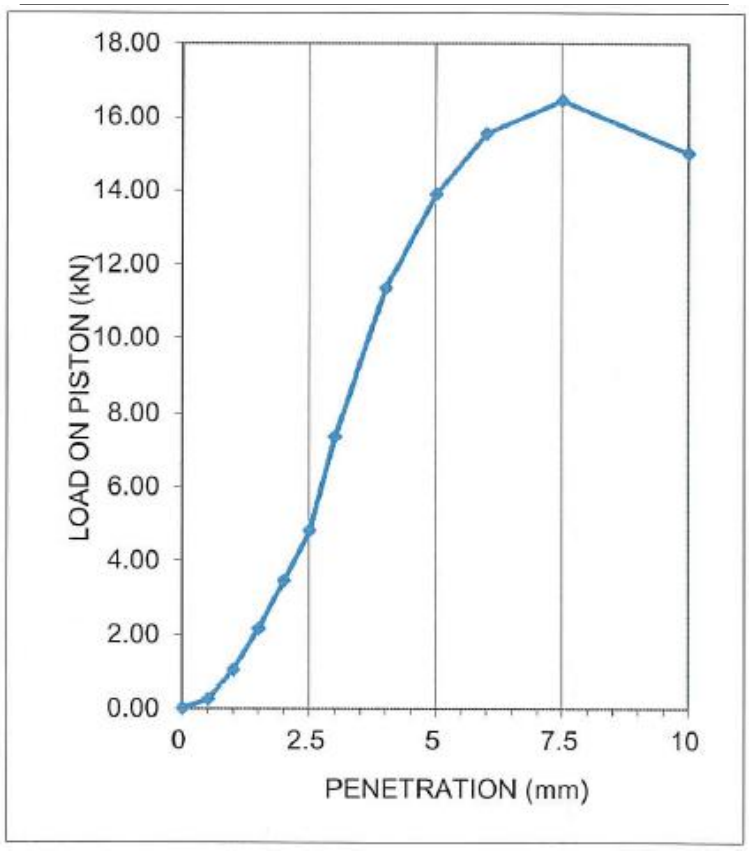
TEST METHOD: AS1289.6.1.1

Compaction Type: Standard
Maximum Dry Density (t/m3): 1.96
Optimum Moisture Content (%) 10.0

Remarks:

TEST CONDITIONS

CONDITION OF SPECIMEN	Soaked (4 Day)
SURCHARGE (g)	4500
PERCENTAGE RETAINED 19mm (Not Included in Sample)	0
MOISTURE CONTENT - TOP 30mm (%)	11.4
MOISTURE CONTENT - Remainder (%)	10.6
SWELL/CONSOLIDATION (%)	N/A
LABORATORY MOISTURE RATIO (%)	98
LABORATORY DENSITY RATIO (%)	100
CBR PENETRATION IN mm	5.0
CBR VALUE%	70



TESTED BY S.G & R.O
DATE: 14/07/2014

CHECKED BY Samer Ghanem
ISSUED- S.G

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

TEST METHODS: AS1289 1.2.1, 6.1.1, 5.1.1 (STANDARD) & 2.1.1

Approved Signatory:

Aargus

Aargus Pty Ltd ACN: 050 212 710
Environmental - Remediation - Engineering - Laboratories - Drilling
446 Parramatta Road, Petersham NSW 2049
Ph: 1300 137 038 Fax: 1300 136 038

REPORT OF THE SOAKED C.B.R. OF A SOIL

CLIENT: DEP Warriewood No.2
PROJECT: Geotechnical Investigation
LOCATION: Fern Creek Rd, Warriewood

Job No. LS5895-2
Report No. N/A
Sample No. MT2
Date Sampled: 2/7/2014

Sampling Location: CBR2/BH8 On Site
Chainage: N/A

Sampling Methods AS 1289 1.2.1 Clause 6.4 b

Depth of Sample: 0.1in-0.35m
Sample Description: Gravelly SAND- Brown/Grey

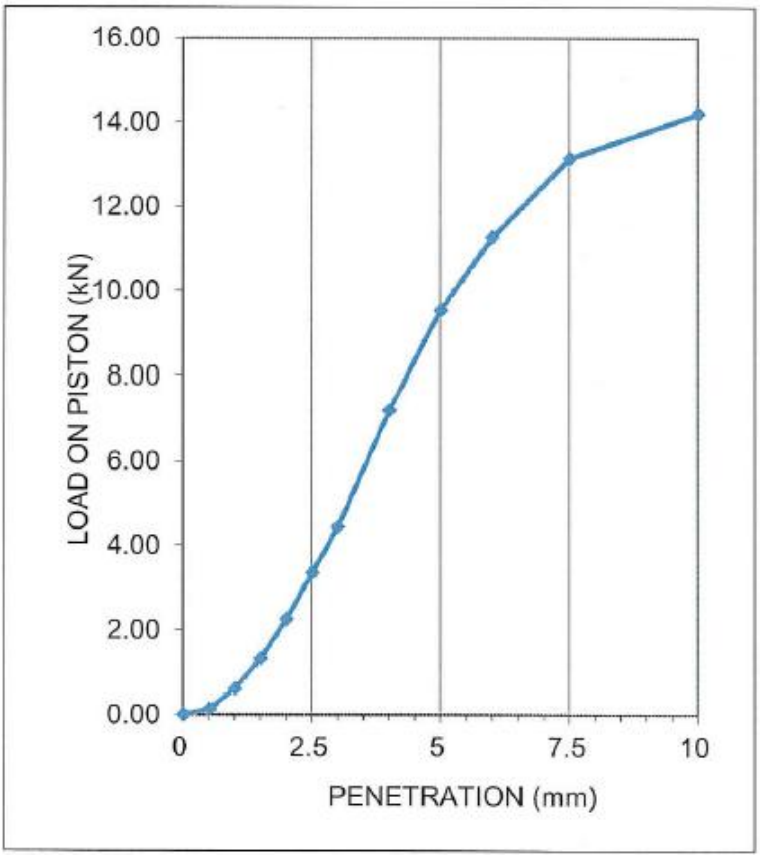
TEST METHOD: AS1289.6.1.1

Compaction Type: Standard
Maximum Dry Density (t/m3): 1.93
Optimum Moisture Content (%): 11.9

Remarks:

TEST CONDITIONS

CONDITION OF SPECIMEN	Soaked (4 Day)
SURCHARGE (g)	4500
PERCENTAGE RETAINED 19mm (Not Included in Sample)	0
MOISTURE CONTENT - TOP 30mm (%)	12.7
MOISTURE CONTENT - Remainder (%.)	12.0
SWELL/CONSOLIDATION (%)	N/A
LABORATORY MOISTURE RATIO (%)	101
LABORATORY DENSITY RATIO (%)	100
CBR PENETRATION IN mm	5.0
CBR VALUE%	60



TESTED BY: S.G & R.O
DATE: 14/07/2014
CHECKED BY Samer Ghanem
ISSUED: S.G

Accredited for compliance with ISO/IEC 17025. The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards This document shall not be reproduced, except in full.
Accreditation No. 12318

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

TEST METHODS: AS1289 1.2.1, 6.1.1, 5.1.1 (STANDARD) & 2.1.1

Approved Signatory

APPENDIX G

GENERALISED CROSS SECTION A-A' (FIGURES 3)

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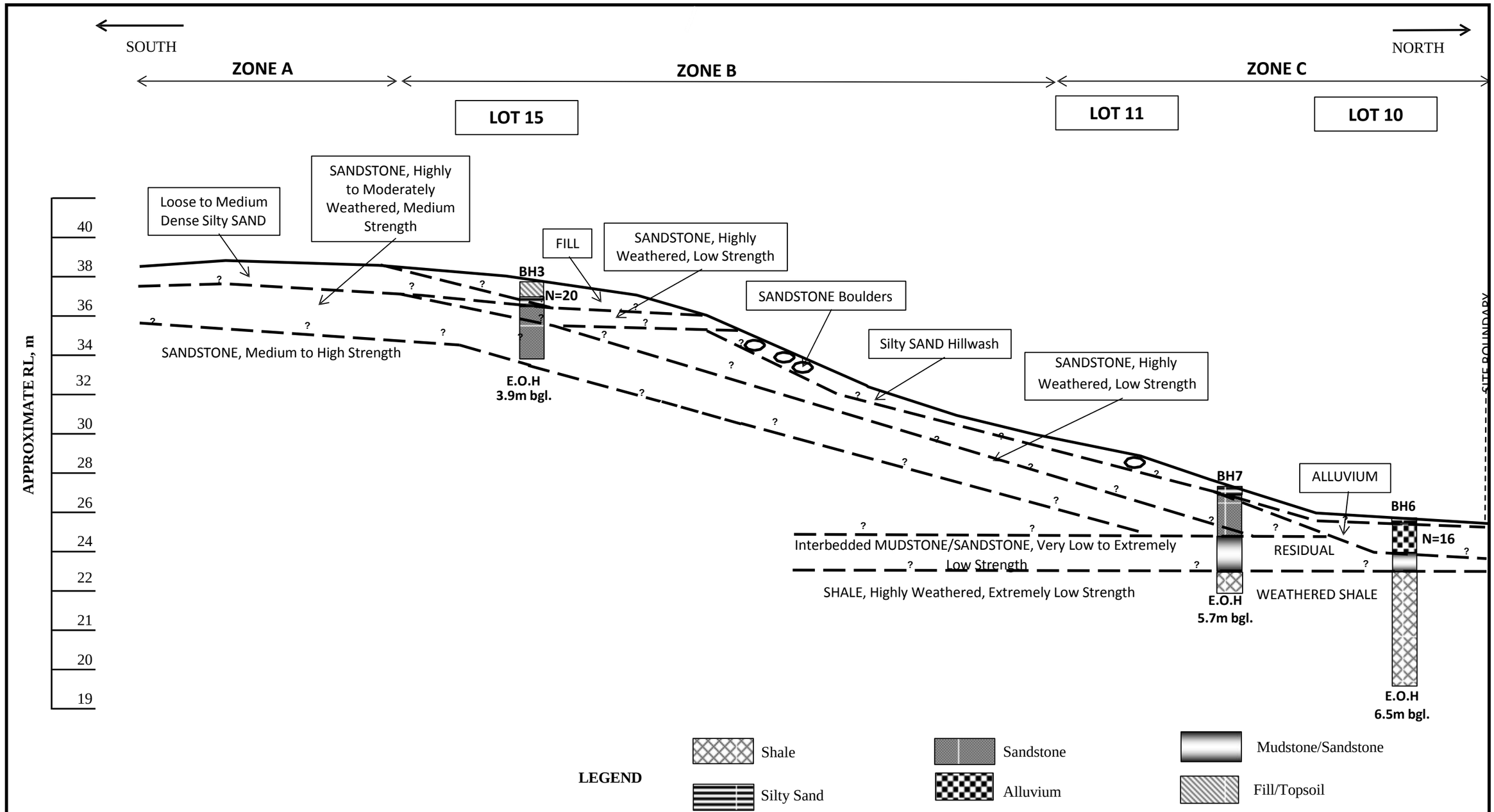

Notes:
1. Do not scale drawing.
2. Water level may fluctuate with time.
3. Depths and RLs are approximate.
4. Standpipe Piezometer measured in both BH7 and BH6 were dry on the 23/07/2014.

Drawn	JN	Client	**DEP (Warriewood No. 2) Pty Ltd**	Figure 3
Checked	DBF	Project	**Geotechnical Investigation**	
Dated	04/08/2014	Address	**No. 1 Fern Creek Road, Warriewood NSW, 2102**	
Scale @ A3	1:200	Title	**Generalised Geotechnical Cross Section A-A'**	Job No. GS5895/2A

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APPENDIX H

CORE BOX PHOTOGRAPHS

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Core Box Photographs

BH4: 1.8m to 3.6m

Core Box Photographs

BH7: 2.7m to 5.7m

APPENDIX I

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION - APPENDIX G OF PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT – AGS 2007C

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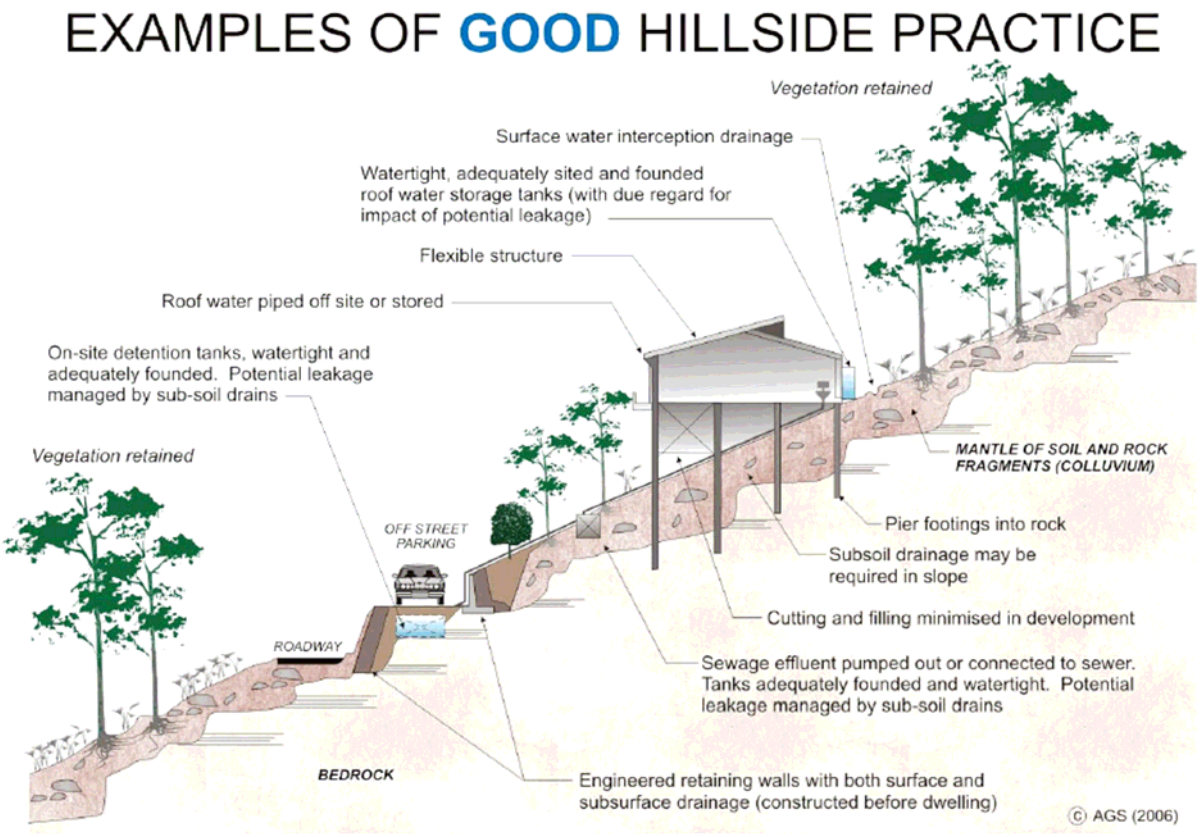
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
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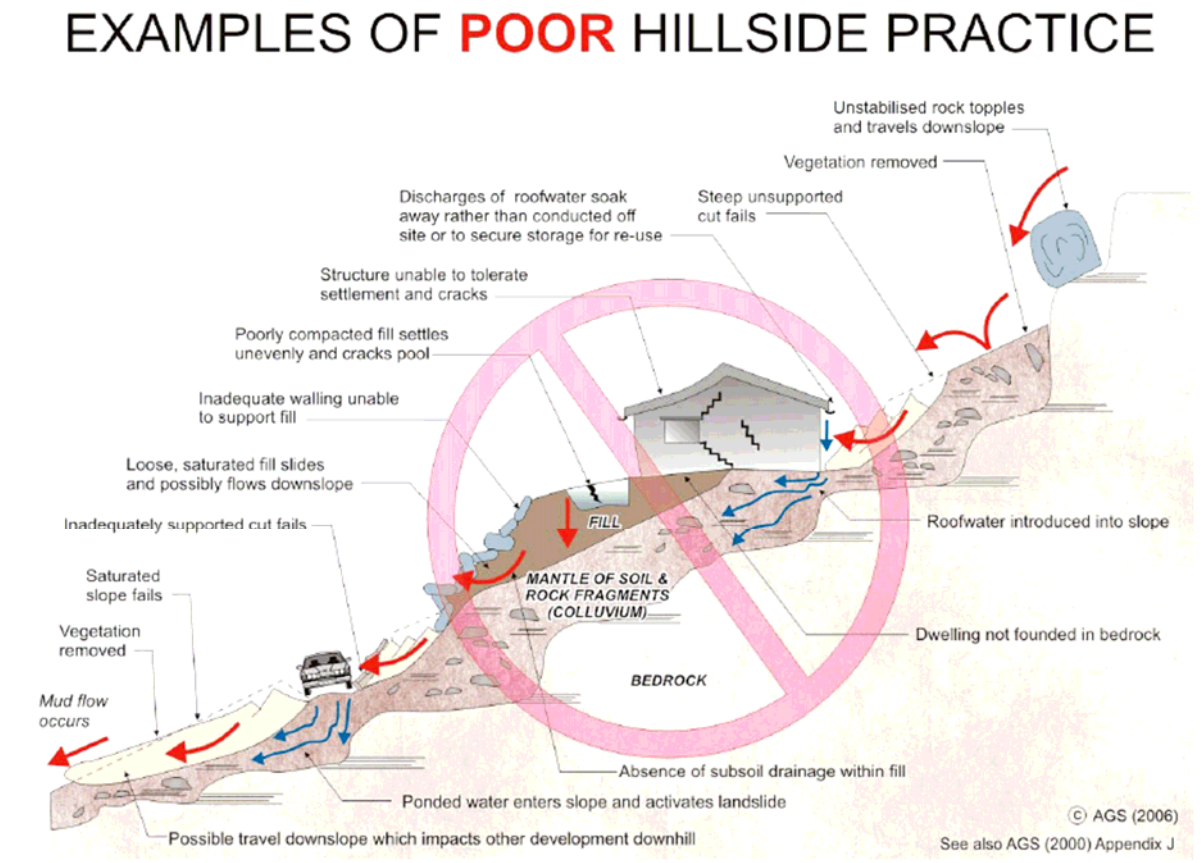
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J